Technology Innovation Project

Project Brief

TIP 278: Transformer Bushing Performance

Context

Throughout the BPA transmission system, high-voltage wires leading into substation transformers are insulated by porcelain bushings on top of the transformer. This material is brittle and susceptible to failure during earthquakes. Although the bushings can be replaced after an earthquake, the loss of a 500kV substation would not only disrupt electricity in BPA's service area, but possibly in surrounding states as well. Substation repairs could involve a significant amount of time during the crucial period following a disaster.

Although earthquakes are inevitable in our region, the damage caused by earthquakes is not. Through research and development, demonstration and implementation, reduction or prevention of harm is possible. By continuing to make the electric power system more resilient to a major seismic event, we can reduce the damage and enable faster post-earthquake resumption of services.

Description

Transformers and their bushings used on the BPA power grid are among the most important equipment needed to maintain a reliable supply of energy.

Currently, center-clamped, uncemented transformer bushings dominate our in-service inventory. Worldwide earthquake performance of these types of transformer bushings has demonstrated their extreme vulnerability to seismic energy, with many failures and significant loss of transformer capacity.

This research project employs alternative testing methods to investigate failure modes of older transformer bushings as well as develop a transformer bushing retaining ring seismic mitigation option. The research will use static pull tests on selected surplus bushings to investigate failure modes and to determine the effectiveness of retainer-ring designs. The final retainer-ring designs will then be tested in a simulated earthquake using shake table testing. The resulting product will be a retainer ring that can be installed on exiting transformer bushings.

Tests performed on surplus bushings will evaluate one of the most common failures modes (bushing slippage and gasket extrusion). Testing will also provide data on bushing boundary conditions and internal core vibration effects for developing a revised IEEE 693 bushing qualification procedure.

Why It Matters

Damage to substation power transformers during destructive earthquakes have prompted the need for seismic retrofits. The most vulnerable part of the whole transformer system is the mounted porcelain bushing, mainly because porcelain is a brittle material and has almost no energy-absorbing capabilities. Failure of the bushing can include oil leaks from connection-interface of transformer/bushing or the fracture of the porcelain body itself.

Using the bushing retainer-ring mitigation option on the many vulnerable transformer bushings will provide significant benefit to BPA at a relatively moderate cost. A major seismic event has the potential to produce up to $5.5 billion in economic losses from direct damage to the BPA system and business losses in the Pacific Northwest due to power outages.

Past earthquakes show that failures can also result from relatively low-intensity ground motions that can occur in small crustal earthquakes affecting a small area of the BPA system.

The static pull testing methodology to determine the bushing failure modes will also support an ongoing effort to improve industry standard IEEE 693 (Seismic Design of Substations). These tests will validate the methodology as a more reliable bushing qualification procedure.

The project also demonstrates that BPA has taken a proactive role in addressing seismic hazards and remains a leader in earthquake vulnerability preparedness.

Goals and Objectives

The goal of this project is to develop a seismic mitigation option for high-voltage power transformer bushings as well as improve testing methods and qualification procedures. Objectives include:

- Develop better understanding of bushing gasket failure
- Investigate a bushing retainer ring mitigation option
- Validate new qualification procedure using static load pull test
- Investigate effects on bushing core natural frequency and bushing boundary conditions

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Project Start Date: October 15, 2012

Project End Date: September 15, 2013

Funding

Total Project Cost:	$220,000
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External Share:	$0
BPA FY2013 Budget:	$220,000

Reports & References (Optional)

Links (Optional)

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Participating Organizations

BONNEVILLE POWER ADMINISTRATION